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WING STRUCTURAL ANALYSIS USING DIFFERENT FIBER REINFORCED COMPOSITES AND HYBRID COMPOSITES

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ABSTRACT

Modeling the wing in ANSYS Mechanical APDL using working model parameters and applying the loads accordingly. The idealization of the wing and all its structural components to a single wing element. Obtaining the results and comparing them. In this project, we are considering different composite materials and their properties. The wing model is generated and meshed to produce required elements and nodes. The Loads are applied accordingly with reference to the working model. When the solution is done, the stress intensity and Von Mises stress of the model for a concern composite is obtained and the same is done for different composites. After obtaining the results, we compare the properties. In this project, we are comparing only stress of the component.

KEYWORDS: Stress Analysis, Wing Analysis & Ansys

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Original Article

INTRODUCTION

The Bell-Boeing V22 Osprey is an American multi-mission tilt-rotor military aircraft with both vertical takeoff and landing (VTOL) and short takeoff and landing (STOL) capabilities. It is designed to combine the functionality of both conventional helicopters and with the long range, high-speed cruise performance of a turboprop aircraft. The major user of this aircraft is also US Airforce. At present, we are having three Ospreys in our airforce squadron. There are many other countries of this aircraft. Due to its flexibility, based on the operable environment and conditions, it can function as an aircraft and a helicopter as well.

Figure 1: V22 Osprey

Many of these aircrafts are used as a military cargo carrier from one base to another base. The U.S.Marine corps uses this aircraft for the survey purpose. These aircrafts are also made available in some of the aircraft carriers for any emergency operations in the naval bases. More than 43% of the V22 airframe structure is fabricated from the composite materials. The wing is made primarily with IM-6 graphite epoxy solid laminates that

are applied unidirectional to give optimum stiffness. The fuselage, empennage, and tail assembly have additional AS4 graphite fiber material incorporated during their fabrication. Many airframe components such as stiffeners, stringers and caps are co-cured with the skin panels. This technique provides subassemblies with fewer fasteners, thus fewer fatigue effects.The composite airframe delivers the necessary stiffness and lightweight for VTOL and STOL. It also provides additional resistance to environmental corrosion caused by salt water. The composite airframe is fatigue resistant and damage tolerant which, a feature particularly desirable is for ballistic survivability. The composite materials were a key technology that enabled the development of V22 and reduced cost and weight, improved reliability, and increased ballistic tolerance. The past two decades of extensive research on composite materials in the aerospace industry have directly benefitted the V22 structural design. **Y. Nakasone et al (2007) (1)** He discussed about the application of ANSYS to stress-analysis problems. One of the problems discussed in the chapter deals with a cantilever beam. To solve the problem, a finite-element method (FEM) analysis of a two-dimensional cantilever beam is undertaken and the deflection of the beam at the loading point and the longitudinal stress distribution in the beam is calculated. The next step is to specify the elastic constants of the beam. In the case of isotropic material, the elastic constants are Young's modulus and Poisson's ratio. This procedure can be performed any time before the solution procedure, for instance, after setting boundary conditions. Another problem in the chapter deals with stress concentration due to elliptic holes. It involves an elastic plate with an elliptic hole in its center that is subjected to uniform longitudinal tensile stress at one end and clamped at the other end. The FEM stress analysis of the two-dimensional elastic plate is performed and the maximum longitudinal stress in the plate is calculated to obtain the stress-concentration factor. **C. Ketelaar et al (2015) (2)** He mainly concentrated on the working of ANSYS and its use in mechanical and aerospace industry. In this paper, he said that ANSYS is a general purpose, a finite element computer program for engineering analysis, which is developed, marketed, and supported by Swanson Analysis Systems, Inc. in Houston, PA. ANSYS has the ability to solve a wide range of structural, electromagnetic and heat transfer problems and is used by the design engineer to determine displacements, forces, stresses, strains, temperatures and magnetic fields. Graphics, preprocessing, solution and post-processing are all integrated in this complete package. These extensive analysis capabilities, in addition to quality customer support and unmatched ease of use, have attracted ANSYS users from many industries including nuclear, aerospace, transportation, medical, petrochemical, steel, electronics, farm equipment and civil construction. ANSYS is an integral part of the overall CAD environment. It can provide information about physical structures – information which is essential to proper design decisions. Engineers may select optimum materials and construction designs which are indicated by the analysis results and incorporate these modifications early in the design cycle. ANSYS users can simulate two- and three-dimensional models including surfaces, shells, springs, beams and others. These models can be subjected to proposed loading and the resulting stress effects are then available for detailed study. **C. Soutis et al (2014) (3)** The growing use of composite material has arisen from their high specific strength and stiffness, when compared to the more conventional materials, and the ability to tailor their structure to produce more aerodynamically efficient structural configurations. In this introductory chapter, it is argued that fiber reinforced polymers, especially carbon fiber reinforced plastics (CFRP), can and will in the near future contribute more than 50% of the structural mass of an aircraft. Of course, affordability is the key to survival in aerospace, whether civil or military, and therefore efforts should be devoted to low cost manufacturing methods in addition to analysis and computational simulation of the manufacturing and assembly process. The simulation of the structural performance should not be neglected, since they are intimately connected. **George Marsh et al (2014) (4).** The use of composites in civil and military aircraft continues to increase. Freelance journalist George Marsh summarizes where the use of reinforced plastics has reached in a number of high profile developments at manufacturers around the world. **C. Soutis et al (2005) (5)** in this

paper he dealt about the applications of composite fibers in aerospace industry. Fibrous composites have found applications in aircraft from the first flight of the Wright Brothers' Flyer 1, in North Carolina on December 17, 1903, to the plethora of uses now enjoyed by them on both military and civil aircrafts, in addition to more exotic applications on unmanned aerial vehicles (UAVs), space launchers and satellites. Their growing use has risen from their high specific strength and stiffness, when compared to the more conventional materials, and the ability to shape and tailor their structure to produce more aerodynamically efficient structural configurations. In this paper, a review of recent advances using composites in modern aircraft construction is presented and it is argued that fiber reinforced polymers, especially carbon fiber reinforced plastics (CFRP) can and will in the future contribute more than 50% of the structural mass of an aircraft. However, affordability is the key to survival in aerospace manufacturing, whether civil or military, and therefore efforts should be devoted to analysis and computational simulation of the manufacturing and assembly process as well as the simulation of the performance of the structure, since they are intimately connected. **Jean P Renaud et al (2001) (6)** This survey paper intends to overview some main technical evolutions impacting the present and future general design of rotorcraft (for vehicles, engines and systems), including helicopter and future tilt-rotor. These trends tend to achieve a better adaptation to a wide range of mission requirements with an economic aircraft optimization and an enhanced safety level and environmental impact. Whilst part I considered the whole rotorcraft technical activity, the present part II is essentially focused on market issues and the tilt-rotor concept introduction. **Donald V Rosato et al (2007) (7)** This chapter provides an overview of Reinforced Plastic (RP) products and marketing aspects effecting RP products. RP products have gone worldwide into the deep ocean waters, on land, and into the air including landing on the moon as well as in spacecraft. The major markets are aerospace, appliances/business machines, building/ construction, consumer, corrosion, electrical/electronic, marine, and transportation. Practically, all markets worldwide uses RPs. Additionally, the chapter describes buildings and constructions; this industry consumes at least 20 wt% of all plastics (including RPs) produced. It is the second-largest consumer of plastics following packages. This amount of plastics only represents about 5% of all materials that industry consumes. RPs continue their use during the past half-century in civil infrastructure such as in highway structures within the USA and worldwide, primarily because their high strength and stiffness to weight ratios and their design flexibility for specific structural characteristics. In addition, the serviceability and functional service life of an RP structure such as a bridge may be greater than those built using conventional structural materials. Investigators continue to develop its environmental durability data

Airfoil Sections

Wing root: Bell A821201

Wingtip: Bell A821201

Dimensions

Length…………… 57.33 ft. (17.47 m)

Wingspan……….. 50.92 ft. (15.52 m)

Aspect ratio……… 5.1

Height……………. 21.75 ft. (6.63 m)

Loads

Based on the type of operation, the loads vary

VTOL …………………………… 52600lb (23589 kg)

STOL……………………………. 57000lb (25855 kg)

Self deploy take off……………... 60500lb (27443 kg)

Single cargo hook ………………. 10000lb (4536 kg)

Dual cargo hooks…………………. 15000lb (6804 kg)

CONSIDERATIONS

Wing type

In this project, the aircraft wing is a plane wing without any tapering nor swept back and also with zero dihedral angle. The aspect ratio of the wing is 5.1, which means, the wingspan is five times the length of the airfoil chord. We are just considering one side of the wing, either left or right, so as to apply the loads effectively without any complications. While considering the wing, we just take the length from root to the tip of the wing, which constitutes a length of 2.55 times the airfoil chord length.

Loads

In this project, we are just considering static loads. The loads will be applied at the tip of the wing. For the aircraft, we have given the different type of loading conditions above. In that, we are considering VTOL with dual cargo hook condition, which constitutes a max load of 30300 kg on both wings. So, coming to the single wing we have only 15150 kg acting on each wing as the load is distributed uniformly on both the wings.

Idealization

In our project, we are just giving the properties of the composite material directly to the generated wing, which doesn't constitute the exact load acting on the wing. So, in order to avoid the error, we have given the properties of the selected material to the generated volume or wing which will be like a skin. In that, we also included the self-weight of the structural components along with the payload. Now, the load will be applied at the wing tip, exactly at the point where the airfoil measures one-fourth the airfoil chord from the leading edge as in the case of the original working model. The load applied will be a point load, as the load is idealized even. It will be like a cantilever beam model and the Stress intensity and Von-Mises stress of the component is generated for a particular composite material, whose properties are given as an input.

Anisotropic/Orthotropic

The composite materials are generally Anisotropic in nature and have 81 elastic independents, but due to the symmetry of stiffness matrix and strain energy function, they will be reduced to 21 elastic independents. These materials exhibit different properties in different crystallographic orientations.

Coming to the orthotropic materials, these have 9 elastic independents and exhibit different properties in different plane conditions and directions. In this, we are considering the materials as orthotropic materials.

MATERIALS

Advanced composites are the composite materials that are traditionally used in the aerospace industries. These composites have high-performance reinforcements of a thin diameter in a matrix material such as epoxy and aluminum. Examples are graphite/epoxy, Kevlar/epoxy, boron/aluminum composites.

The composite materials here we are using are Carbon, Graphite, and Kevlar. The material properties are as follows.

Table 2.1: Material Data

Material	Carbon Fiber Composite	Graphite Fiber Composite	Kevlar Fiber Composite
E_1(GPa)	164	175	195
E_2(GPa)	12.8	7	14.6
E_3(GPa)	12.8	7	14.6
G_{12}(GPa)	4.5	3.5	7.5
G_{23}(GPa)	2.5	1.4	5
G_{31}(GPa)	4.5	3.5	7.5
ν_{12}	0.32	0.25	0.3
ν_{23}	0.45	0.01	0.45
ν_{31}	0.32	0.25	0.3
ρ(Kg/m^3)	1800	1550	1400

METHODOLOGY

Finite component analysis package ANSYS 14 APDL (ANSYS constant quantity, style Language) has been used for analysis within the gift work. During this tool there square measure variety of component varieties, that is needed to model a superimposed kind structure. During this analysis, Element shell 281 is chosen, because it is appropriate for analyzing skinny to moderately-thick structure, well -suited for giant rotation, has six degrees of freedom, nonlinear giant strain and linear applications. The pure mathematics, component, system, the node location and component consistof shell section data and eight nodes. ANSYS consists of solid to flexible and flexible to flexible contact component, for this it needed contact and target surface to form the contact combines between filler and plate. Here during this work CONTACT 174 and TARGE170 has been used. TARGE170 is employed to represent varied 3-D "target" surfaces for the associated contact components COTAT174. TARGE170 is outlined by a collection of target section related to contact surface and also the solid, shell or line component represents as the boundary of deformable body. CONTA174 is outlined by eight nodes and might degenerate to a sixnode component conjointly support the isotropic and orthotropic Coulomb friction looking at the form of solid or shell components. The target surface is often rigid or deformable, it depends on the natural object and kinds of contact combine. The outward vector of target and call component ought to be traditional to the surface and it ought to have real constant set to form the contact combine. Every target surface is often related to only 1 contact surface, and vice-versa. However, many contact components will create the contact surface and a number of other target components will create the target surface and therefore are available contact with the same target surface and call surface severally. The areas and volumes generated by the specific coordinates are not related to each other anyway, they have to be interconnected to each other and the system should accept it as a single element. Initially there will be no nodes present in the coordinate system, in order to generate the nodes the entities should be undergone meshing aerially and also by volume dividing the single element into number subelements so that we can apply desired loads and specify desired loading conditions at a particular node of the element. The entity is meshed aerially and later by entering a precise value with sweep option, we can make the volumetric meshing.

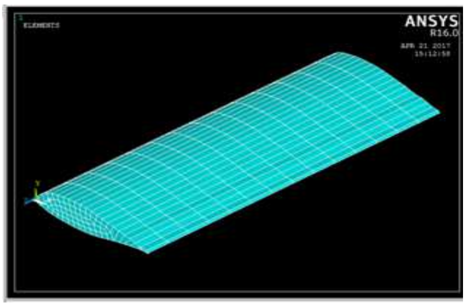

Figure 2: Elements Generated after Meshing

From the solution above model determine the following properties of the model

- Deflection in the model
- Stress intensity at every point on the model
- Von Mises stress in the model

RESULTS AND DISCUSSIONS

The plots that have been obtained by contours will be represented as follows. Due to the application of point load at the free end and restricting deflection in all directions at the other end. these results have obtained. Wing itself behaves like a cantilever beam so as applied load according to that.

DEFLECTION

From the application of load wing has deflected as shown in following Figure 3, Figure 4 and Figure 5 carbon fiber composite, kevlar composite and graphite composite respectively. From the result we conclude that graphite and carbon fiber has more deflection per load as compared to graphite composite. This may be due to the unique character of Kevlar is When the melted Kevlar is spun into fibers, the polymers have a crystalline arrangement, with the compound chains adjusted parallel to the fiber's axis. The organic compound teams square measure able to kind chemical element bonds between the compound chains that act like glue holding the separate compound chains along.

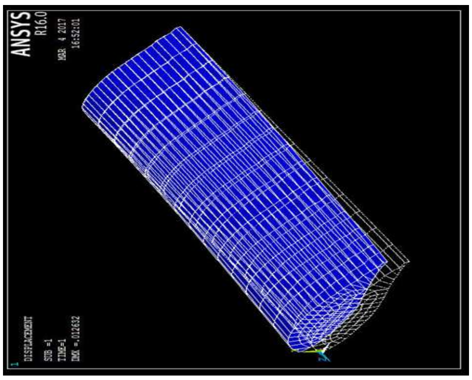

Figure 3: Carbon Deflection

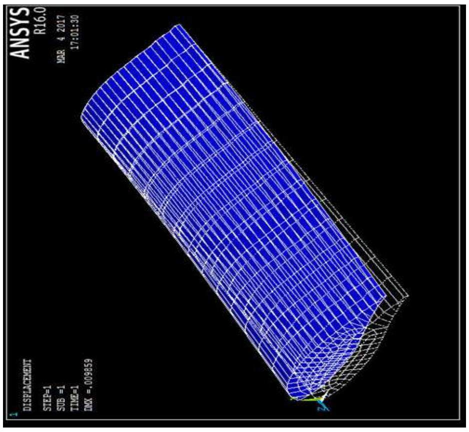

Figure 4: Kevlar Deflection

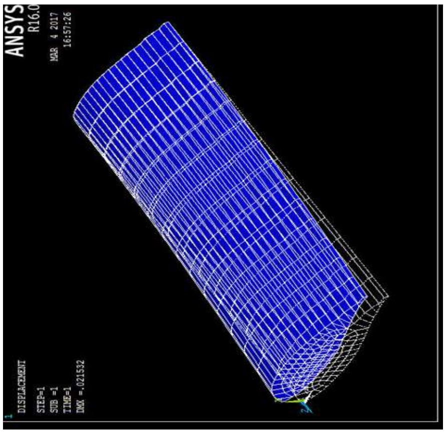

Figure 5: Graphite Deflection

From the above plots, it is clear that the deflection in different types of composite models is varied based on their strength. The max deflections in the models are listed below.

Table 4.1: Wing Deflection Data

Material	Deflection (mm)
Carbon	12.632
Kevlar	9.859
Graphite	21.532

So, in Carbon and Kevlar materials the deflection of the wing is more when compared to that of Graphite.

STRESS

From the loading conditions of wing it shows the variation of stresses from the free end to fixed end. The variation of stresses as shown in below Figure 6, Figure 7 and Figure 8 for carbon composite, kevlar composite, and graphite composite respectively.

Stress Intensity

This stress intensity is largely called stress intensity issue that is employed in fracture mechanics to predict the strain at a crack caused by a load. it's denoted by K. The magnitude of K depends on the sample pure mathematics, the size, the magnitude and also the modal distribution of hundreds on the fabric. From the results, it is concluded that stress intensity variation from one end to other ends for kevlar composite is less than compared to carbon and graphite composite.

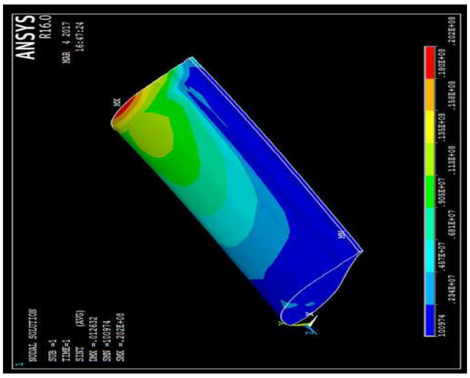

Figure 6: Stress Intensity of Carbon Composite

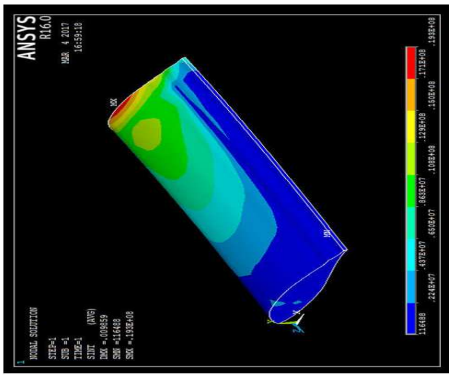

Figure 7: Stress Intensity of Kevlar Composite

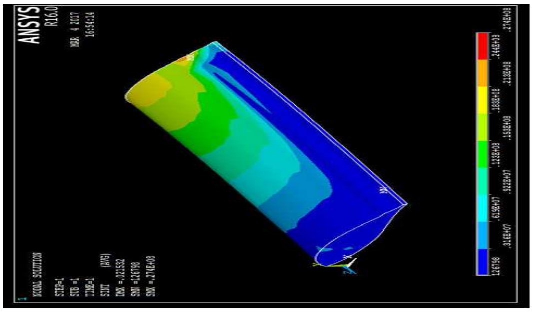

Figure 8: Stress Intensity of Graphite Composite

The trend in the stress intensity of different composites is given in the table below

Table 4.2: Maximum and Minimum Stress Intensity

Material	Stress intensity	
	Minimum	Maximum
Carbon	100974	$0.202*10^8$
Kevlar	116488	$0.193*10^8$
Graphite	126798	$0.274*10^8$

Von Mises Stress

In material science and engineering, the von Mises stress σv is a scalar stress value that can be used to predict the yielding of materials under any loading condition from the results of the simple uniaxial tensile test. A fabric is alleged to begin yielding once its von Mises stress reaches an essential price called the yield strength, σy. From the results, it is concluded that kevlar is having minimum stress distribution than graphite and carbon composite.

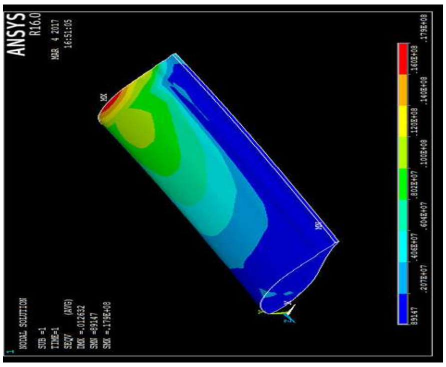

Figure 9: Von Mises Stress of Carbon Composite Model

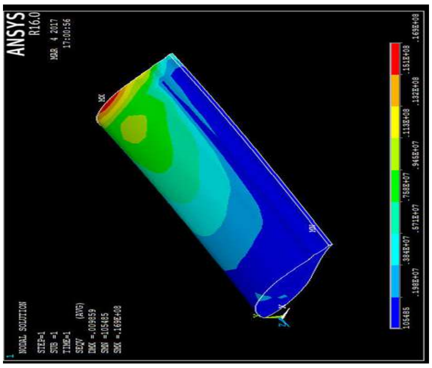

Figure 10: Von Mises Stress of Kevlar Composite

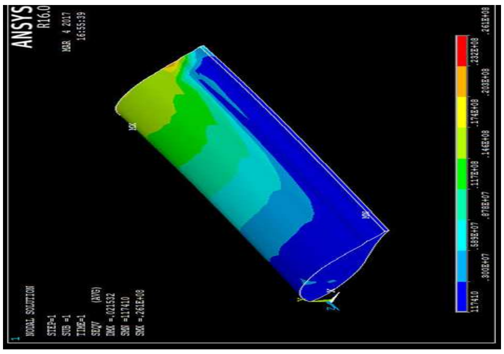

Figure 11: Von Mises Stress of Graphite Composite

The trend in von mises stress of different composites in wing model is as shown below

Table 4.3: Minimum and Maximum Von Mises Stress

Material	Von Mises Stress	
	Minimum	Maximum
Carbon	89147	$0.179*10^8$
Kevlar	105485	$0.169*10^8$
Graphite	117410	$0.261*10^8$

CONCLUSIONS

From the obtained results, the stress intensity and von Mises stress developed in the graphite is relatively more compared to that of both Carbon and Kevlar composites. For a composite, more the stress intensity, the deformation in that particular composite will be less. In the same way, more the von Mises stress value, the less is the crack propagation chances for a particular loading condition, if the value is less than its yield point. So, we can say that Graphite is the best composite among the three of them what we have analyzed. Even though von Mises stress is more in graphite, the value is less than its yield point as shown in the figure. In most of the Osprey parts like wings and their structural members, graphite is more preferable along with some epoxy systems in order to enhance the strength and the deformation capacity of the aircraft parts

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